E/CONF.39/A/140
18 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.1

United Kingdom

MINING EXPLORATION METHODS

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MINING EXPLORATION METHODS

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Introduction

1. Mining to many signifies the extraction of somewhat uncommon metals or minerals such as gold, copper, nickel, lead, aluminium, diamonds, asbestos, iron, coal. To those who live in rather special geological areas, mining means the business of extracting one particular metal or mineral, e.g. gold in Ghana; tin in Nigeria, Malaya and Indonesia; uranium in the Congo; copper in Katanga; bauxite in Guiana; lead, zinc, silver or rubies in Northern Burma. Such a situation has given rise to wealth in a broad sense of the word to the area concerned. However, it and the mining laws it has brought about, has some times cause a narrow local view on exploration. It is appropriate to take a new look at those areas where mining and exploration methods have become traditional through the structure and policy of private enterprise mining corporations who deal in selling ore to world markets and to the mining and exploration laws of the country concerned which may be in need of revision.

2. A government, in a less developed area, honestly trying to use its country's own natural resources to the benefit of its own country folk, will be attempting to obtain a knowledge of the kind and quantity of its natural resources in order to diversify its economy. In the field of mining it will be assessing the value of the deposits which are being and can be mined in terms of export and of value to the people themselves - work, money, energy, level of living, health. It will be justifiably perturbed if its mineral economy is virtually mono-mineral (or metal) and will be concerned to diversify its mining.

The Concept of Systematic Mineral Exploration

3. It can be assumed now that chance discovery of ore can be ruled out of any exploration plan or policy. If it occurs, and it is still possible in some parts, it will be good luck; but exploration policy should not be conditioned by such a possibility. A systematic search for ore is the basic concept for the future by Government. "Ore" should be considered in the widest possible sense. "Ore" is any naturally formed substance extracted from the earth which is of use to mankind. It, therefore, embraces metals; sedimentary materials such as coal, peat, oil, phosphates, salt, clays and the like; quarried stone, slate, limestone, road and building materials. It may be found not only on land but also under lakes and under the sea. To be practical at this present time, sea areas are defined as those being close to the shore, within

practical depths of water and thus within territorial limits.

Choice of Area

4. The starting point for systematic mineral exploration is the choice of an area in which to begin. This choice is made from a consideration of (a) the general type of ore sought; (b) areas geologically hospitable to that type of ore; (c) the location of the area in relation to working, transport, treatment and marketing of the substance mined.

Type of ore

(a) The type of ore sought will depend on the organisation searching. Mining corporations will generally be looking for ore which will be valuable on the world market some years ahead. It takes perhaps five to ten years from the discovery of ore to the first run of ore through the treatment plant. Herein lies a major hazard for private mining finance. On the other hand, a government organisation designed fundamentally to be of service to the community will look for ore from a national point of view. They will consider amongst other things such factors as, for instance, (i) the domestic needs in the country concerned, i.e. needs for power (energy) for public utilities, employment of the people, raw material for existing manufacturing undertakings, defence of the country; (ii) the capability of local personnel and services to mine and treat the ore; (iii) the availability of national money to finance the work; and (iv) the diversification of the national economy generally and, in particular, diversification of the economy of particular areas.

Geologically favourable areas

(b) The choice of geologically favourable areas depends on the availability of general geological information in the country concerned. The amount and usefulness of such data varies greatly from country to country. There is a lack of such general information in many land areas in the world. The reasons are simple. Geology is a field science. Its laboratory is the world in general and even a particular problem covers a large part of the earth's crust - a whole mountain range, a swamp area. Geological units are vast in physical size compared to the units used in experimentation or study by the physicist, chemist, metallurgist, and engineer. Getting the facts to work on is thus a major problem. Moreover to understand the geology, it is necessary to use the knowledge of many sciences. Not only have these had to advance to a state useful to the geologist (and some of them have done this rather slowly), but also co-ordinating effort between the sciences has been a big factor. Perhaps, however, the biggest factor has been that of collecting data from which to understand, map and describe. It is submitted that this is the biggest single technical factor which has delayed mineral exploration activity in the so-termed under-developed areas of the world. There is much that can be done about it. The methods and techniques which can be used, and which are generally described below, apply not only to government planning, but also to private enterprise planning though generally perhaps it is considered that this type of work is the business of government.

Regional Fact-finding and Mapping Methods

5. (a) The systematic search for ore in a country will start as a

priority in that area chosen, from the foregoing factors, as the most promising. The choice will be best made if the regional geology of the country at least is well understood. If the area has to be chosen on meagre geological information, it will still be necessary to know the regional geology of the chosen area before systematic ore search is possible.

(b) Methods of regional geological surveying involve the techniques of field mapping and laboratory study, aerial photography and the interpretation of such photography, airborne geophysics, applied geochemistry, and heavy mineral sampling.

6. Ideally, these techniques should be incorporated into framework of a general fact-finding mapping programme designed and managed by experienced technical people. There should, however, be no thought that there is a unique programme applicable to all areas nor that a programme once initiated, should be so rigid that changes in the light of progress and evidence gathered cannot be made. There are, however, basic technical concepts that could well be adopted and are universally applicable whatever the area:-

(a) Speed in gathering facts.

(b) Practical scope and specification for the mapping.

(c) Consistency in gathering facts and in presentation of these facts.

(d) Consistency in direction and management.

7. Speed is important. This does not mean haste. The pace at which the programme goes will be determined by the amount of effort (man and equipment) that can be put on to it, by the specification (or scope) of the work defined at the outset and by the techniques used in the programme. The pace of the programme should be designed to be fast. We must remember that fact-finding surveying is only the very first step in a long process leading to ore. This means modern techniques must be used. It is really no use such a programme being deliberately designed to take, say, a hundred years. The economy of a country and the potential users of the results of such a programme, be it government agencies or private enterprise, cannot wait that long.

8. (a) The scope of the programme will vary with the area, of course, but it should be defined by the need to produce factual maps of practical use in mining exploration, say, within the next decade, not perfect examples of mapping for museum purposes. Such refinements can come later. They are properly the prerogative of applied research groups (government or private) and will come most economically and logically by virtue of detailed work by many groups of people after broader regional geology has been mapped by the techniques described. Whilst the government geological departments in many parts of the world have set the standards of quality of geological mapping, the time has come when either by widening their scope or by instituting sister organisations, the emphasis should also be on the production of useful factual maps rather than solely on the production of perfect, detailed geological maps. Some governments have accepted this.

(b) For the scope of the mapping programme to be practical, it is implied that the various potential users have been consulted and the scope worked out with them.

9. Consistency in gathering facts is important. It would be inappropriate, for instance, for the geologists, geophysicists or geochemists generally to attempt to work to a degree of detail which cannot be presented on the maps because of scale limitation or to an accuracy which is inconsistent with the accuracy of the topographic maps. It would, for instance, not be sense to use geophysical methods which are designed for detailed problems and not for regional work.

10.(a) Consistency in direction and management is an ideal to be aimed at. Consistency in direction presupposes that the programme fits into a general resources plan which will be pursued throughout the life of the mapping programme and further, that if the overall resources plan is likely to be modified, then the mapping programme is capable of logical modification too. It presupposes that the person, committee or body of men directing the programme is competent and consistent and acts in a way that is acceptable to the users of the maps produced.

(b) Consistency of management implies a simple organisation with competent experienced people in key positions. It implies that the programme will not get side tracked technically on to studying detail outside the aims of the programme.

(c) Overall, both direction and management should have the best possible continuity or else the enthusiasm of the project will drop. Ultimately, it is the personnel involved more than the techniques used which will determine the success of the programme. The morale of these personnel is important.

Base maps and mapping materials

11. The mapping of field detail relies on having a map on which to map. The modern techniques of producing such maps is by photogrammetry. Generally, one would nowadays plan to have airphoto cover of the area fairly early on in the programme. It need not be right at the start, since other work can start before it is obtained. It is probable that, over any area you like to choose, airphoto cover of some sort exists. This may be at a scale and of a quality that can be used for, say, a preliminary photo-geological study or as navigational material for air geophysical flights or location of streams etc. for geochemical field work. Existing airphoto cover can usually be used in some way, but it may, particularly if it is old, be too limited to use for long on the programme.

12.(a) The question of flying new photo-cover may arise. The specification for it will have to be decided on by surveyor, geologist, geochemist. It is hoped a compromise really acceptable to none can be avoided.

(b) Scales of air photography can be anywhere from, say, 1:10,000 to 1:60,000. The popular scale for photo-interpretation is 1:30,000 to 1:40,000. It ought, of course, to be larger than the scale of the final mapping.

(c) The quality and specification of the photography is important. Modern air camera lenses are generally excellent. Modern lenses of six inches and eight and one-quarter inch focal length give very acceptable definition and coverage for the interpreter and field man. The newer super wide angle lenses of, say, three and one-half inch focal lenses and a one hundred and twenty degree angle of view, however, produce some problems for field man and interpreter. It is general to use a nine inch by nine inch format though a seven inch by seven inch format is some times used. It is general to have a forward overlap of sixty per cent for stereoscopic viewing with a twenty-five per cent lateral overlap between runs which should be straight flown and continuous. One expects that the tip and tilt of the photography is kept within good limits of levelling and that the mechanical and electrical parts of the equipment are functioning so that, for instance, consistent overlap and precise focussing is obtained without image movement. The base used for the film itself must be stable enough to be acceptable to photogrammetrists.

(d) The use of colour photography will come - great strides are being made to get correct colour, enable higher flying, reduce processing costs and the like. For the present, the advantages are doubtful. Sometimes colour alone is a disadvantage.

(e) Infra-red photography has been used where standing water and vegetation make normal panchromatic film unacceptable.

(f) The type of topographic maps usual on regional mineral exploration programmes is planimetric (e.g. features not heights) produced by a low, but consistent order of photogrammetric technique, namely slotted template. Consistency in scale is obtained by having a useful number of astrofixes (or better) placed throughout the area. From such a framework not only "line" or "planimetric" maps to act as a basis for data are produced, but also photo-mosaics, found to be most valuable in field work.

(g) For various reasons, the production of controlled maps and mosaics may not be possible. In this case, so-called uncontrolled mosaics are often used. They clearly have disadvantages, not the least of which being duplication and omission of ground detail due to the fact that ground surface is only occasionally truly level.

Photo-interpretation and field work

13. The scope and system used in photo-interpretation varies. It has been generally proved, however, that the best schemes involve the interpreters working not only on the photographs but observing in the field also. A customary programme would involve (a) laboratory pre-field photo-study plus a library study of known data; the photo-study being a rapid one aimed at working out broad features and patterns and pointing up the key points to visit in the field; (b) field study based on (a) to solve problems, develop photo-keys and collect vital information not only in the field, but also available locally, unpublished, in files, in the compilation stage or simply in the local peoples' thoughts; (c) post-field collating, revising, reviewing, deciding, followed by presentation on map and in report. As a guide the following data may be useful:-

> Area 30,000 square miles; scale of photography 1:40,000; number of geologists 7; programme:- four months pre-field, six months in field, six months post-field; final mapping scale 1:50,000.

Regional geophysics

14.(a) In technical circles there is much controversy over the proper use of airborne geophysics, particularly in regional geological mapping programmes. Some hold it should be used as a localised exploration technique or to assist in the solution of particularly geological problems. That is, used over specific (probably small) areas after the basic geological mapping is done. Not until then they claim, can the geophysical survey specification be defined nor the results interpreted in a useful way. Others hold that large areas should be covered automatically (preferably by the same aircraft unit to save expense) by all available methods (e.g. magnetic, electromagnetic, radiometric and possibly gravity) and that the data obtained should be compiled and held against the need to assist in the solution of specific geological or mineral location problems. A third body of opinion holds that regional geology cannot be done thoroughly and rapidly without using air geophysics at an early stage integrated right into the regional geological mapping. It holds further that the storing of uninterpreted geophysical data is wasteful since only when interpreted in geological terms, does it begin to be useful at all to the field geologist. From the writer's experience, the third view is the more correct one. It involves, of course, the closest possible contact between the geophysical, geological and mining people concerned throughout the project. This can be achieved and is being achieved on U.N.S.F. and A.I.D. projects in being now or recently carried out.

(b) It is clear that magnetic and radiometric data obtained by a well designed and controlled air survey and competently interpreted on the basis of even fairly sparse geological data by a team composed of scientists of complementary field disciplines can produce fundamental geological information in remarkable density which is absolutely essential at a very early stage in geological mapping. The very dense framework of geological information given by the method enables the field worker to work from the framework down to the detail and moreover enables him to work much more efficiently and quickly in the field. This concept of establishing the framework first then proceeding to work out the detail within the framework, is accepted as ideal in topographic and geophysical surveying, but has not yet been accepted generally in geological circles. It should be, now there are methods available for doing it.

(c) At the present time, the air magnetic and radiometric methods have been developed and their results understood enough to use them as first line regional geological mapping methods. The air gravity method is in its infancy and the air electromagnetic methods developed so far fall more into the category of methods applicable to special problems and geological situations.

(d) There is much to grasp in the design and conduct of such surveys to get the best results cheaply - for the methods are cheap. Perhaps the ideal sequence for a programme involving air geophysics and geology would be:- (i) Very preliminary photo- and library geological study on which to base the specification of the air geophysical survey. (ii) Design and execution of air geophysical survey. (iii) Interpretation of air geophysical data and initial regional geological field work, running together. (iv) Next stage field geological work with mineral exploration on targets found, running in parallel.

Regional geochemical prospecting

15.(a) Methods of applied geochemistry are well established. Techniques of a regional nature involve soil sampling and stream sediment sampling and cover a wide range of metals. The field work is some times economically speeded by the use of helicopters for transporting men and samples. Care is necessary to see that the capability of the laboratory(ies) used is sufficient to keep pace with the field work. It is also essential to perform preliminary tests called "orientation studies" to define the specification for the geochemical survey. The main thing, of course, is to establish (i) that the method in general will work in the area chosen, and then (ii) that the technique which will be most practical and successful is used.

(b) Data is presented on planimetric maps similar to those used for geology and geophysics. In the field, air photographs giving as they do an abundance of detail, are the best location mapping and recording system.

(c) It is time more thought was given to including regional geochemical prospection methods into regional fact-finding mineral resources mapping programmes.

Heavy mineral sampling

16.(a) Heavy mineral surveys are similar in concept to geochemical stream sediment sampling. The field techniques used are different however. Samples are taken from stream beds where changes in water velocity have given an accumulation of heavy minerals.

(b) Whilst the method has been used during routine field geological mapping in the past, it has been more recently used as a rapid field method to meet a specific mining exploration problem. There is no reason why it could not be integrated into a multi-method fact-finding survey at an early stage of a mineral exploration programme.

Methods of Intensive Mineral Exploration

17.(a) As the results of the systematic regional geological/mineral mapping programme come to hand, areas (targets) for intensive exploration study and effort will be revealed. This is where a wide variety of methods can be employed to assess the potential value of the ore.

(b) Target areas may have been quite precisely defined by the systematic survey or the result may be wider zones of interest. The physical size of the area of the target or zone will dictate to some extent the exploration methods used. The methods applicable are perhaps conveniently grouped into geological, geophysical, geochemical and mineral:-

(i) Geological methods include:- Larger scale field mapping and associated detailed photo-interpretation, involving as it may special air photography and contour mapping. Exploratory drill holes, trenching, pitting and exploratory addits. Structural geological mapping using borehole etc. data.

(ii) Geophysical methods include:- Magnetic - airborne (fixed wing or helicopter) or ground; total field (fluxgate, proton, or other systems) or component (Schmidt balance or Torsion etc.); surface or borehole. Electromagnetic - airborne (fixed wing, helicopter) or ground; horizontal

or vertical loop; Afmag. Induced polarisation. Resistivity (many systems for deep or shallow penetration). Self-potential. Radiometric - airborne (fixed wing or helicopter) or ground; geiger counter or scintillation counter; surface or borehole. Gravity. Seismic - shallow or deep; single, two geophone or multi-channel.

(iii) Geochemical methods would be soil or stream sediment with a definite metal or metals in mind.

(iv) Mineral methods include heavy mineral prospecting; assaying of samples.

(c) Depending on the target size, mineralisation, type, etc., a combination of the methods noted above would be used.

Reporting, storing results and original samples

(d) It is, of course, absolutely essential, if effort is not to be wasted, that all such detailed work is adequately reported by word and map and that samples, drill cores, measurements, etc., with accurate location descriptions, are retained. This is altogether a big organisational problem which should be faced up to. The cost of obtaining data and samples is appreciable and even this alone justifies consideration for retaining such information for review periodically as geological thinking in the area advances.

General Conclusions

18.(a) Methods of mineral exploration are used to the best advantage if they are carried out within the framework of planned programmes - not over-planned or vast programmes, but well conceived, well directed programmes of useful size and scope.

(b) Man power in mineral exploration should be used economically and the results of such effort not wasted for the future. They can be used economically if the exploration programme is well conceived and the methods and techniques used are modern. The results can be of lasting use if they are retained in suitable fashion. It is important but difficult to retain concepts and enthusiasm throughout an exploration programme. This is best done by maintaining continuity of thought through personal contact. It is appropriate in this United Nationsl Conference to note that this aspect must be a major pre-occupation of those in Special Fund and indeed in F.A.O., concerned with designing aid projects. The hope for continued direction, management and continuity of knowledge beyond the time when the aid agency ceases actively on a project has been stressed in recent "Recommendations" by the Managing Director, U.N.S.F. It is an aspect that should rightly be stressed; the difficulty being how to achieve it, particularly in those countries where such a programme is timed often by design to occur when there is a change over from expatriates to nationals in the government departments concerned.

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